TO: Director, National Institute for Occupational Safety and Health

FROM: California Fatality Assessment and Control Evaluation (FACE) Program

SUBJECT: Shipfitter/welder dies when an oxygen cylinder explodes in California

SUMMARY
California FACE Report #96CA009

A 45-year old male shipfitter/welder (the victim) died when an oxygen cylinder he drilled into during a salvage operation exploded and propelled him into a stationary band saw. The shipfitter had been asked to drill and cut up acetylene cylinders that were marked with an "X" in a circle. The oxygen cylinder had the same marking. The company had no written procedures on the destruction and salvage of compressed gas cylinders. The CA/FACE investigator concluded that, in order to prevent similar future occurrences, employers should:

- Assure each gas cylinder marked for destruction is labeled or marked to differentiate them from those not ready for destruction.
- Use an unmistakable marking on cylinders that have been prepared for salvage or destruction.
- Prepare an appropriate written program describing the procedures for the destruction and salvaging of compressed gas cylinders.
- Use an appropriate method for the destruction of pressurized compressed gas cylinders.

INTRODUCTION

On June 6, 1996 at 7:05 a.m., a 45-year old male shipfitter/welder died after he was propelled into a stationary band saw by an exploding oxygen cylinder. The CA/FACE investigators were informed of this incident on June 14, 1996 by the Los Angeles county coroner's office. In an attempt to make a site visit, a CA/FACE investigator was initially denied access by company attorneys**.** A visit to the Cal/OSHA district office where the evidence was stored and site visit to the place of the incident was made by a second CA/FACE investigator on July 2, 1996. The first CA/FACE investigator visited the Cal/OSHA district office on August 1, 1996 to examine and photograph the impounded evidence.

The employer in this case is a ship repair company that had been in business 15 years and 4 months at the site. The company employed 1224 workers with 195 working at the location of the incident. The decedent had worked at the site and for the company for 9 years and 8 months. Although there were no written procedures for the task the decedent was performing, he did receive verbal training. The company's quality assurance manager conducted a hazard identification survey

prior to work beginning. He also functioned as the person responsible for safety on the job and devoted 50% of his time to safety duties.

INVESTIGATION

The scene of the incident is a shipyard where the company involved performs ship repairs. It occurred in a building known as the structural/shipfitter shop. The building is large, has many windows, and is constructed of corrugated steel. It had trolley rails run through it from one large bay door to another. A flatbed trolley ran on the rails through the shipfitter shop and was used to carry materials and equipment in and out of the building. Placed just outside of the southwest bay door were storage racks for compressed gas cylinders **(Exhibit 1).**

The job in progress at the time of the incident was the destruction of compressed gas cylinders. Any remaining pressure in the cylinders was bled off over a twenty-four hour period. They were brought into the shop on the trolley, drilled, if appropriate, cut and the metals then salvaged. The cutting was done with a stationary band saw.The company's quality assurance manager provided verbal instructions before any compressed gas cylinder salvaging was begun. He gave these instructions to the general foreman of the shipfitter/welding department as well as the decedent's supervisor. It was left up to the supervisor to pass on the information to his employees, including the decedent. The supervisor stated that he instructed those shipfitters who would be involved in the project as to how it should be done. None of the procedures or training were documented.

One day prior to the incident, a shipfitter/welder working for the company had cut two or three oxygen cylinders. He had opened the valves using only his hands to relieve the pressure. He cut the cylinders into pieces with the stationary band saw. Many of the cylinders were quite rusty and, although there is some discrepancy, it is believed he had to cut off some of the valve caps to access the valves. The decedent had not worked with gas cylinders on this day. The day before the incident, the decedent and his supervisor had evacuated three (3) acetylene cylinders by bleeding off the acetylene gas. The supervisor discussed the destruction and salvage of these cylinders with the decedent at that time. The destruction was scheduled for the following day. The supervisor and the decedent checked the cylinders the morning of the incident to assure that cylinders were void of gas and depressurized. The supervisor stated that he placed his hand on each cylinder that he wanted to scrap, two of which were in an enclosed holding area near the storage racks and one just outside the holding area. He then left the area.

The decedent loaded the acetylene cylinders as well as an oxygen cylinder onto the trolley. The acetylene cylinders which were designated for destruction were marked with a "X" surrounded by a circle. The oxygen cylinder the decedent had placed onto the trolley had the same marking. The trolley was pulled into the shop area. The decedent had prepared a portable drill motor and bit **(Exhibit 2)** in the shop area. Acetylene cylinders contain a fibrous mass and acetone in addition to the acetylene gas. Once they had been relieved of gas, the procedure was to drill into the acetylene cylinders to remove the acetone prior to cutting the cylinder into pieces with the band saw.

While the cylinders were still on the trolley, the decedent began without lubricant, to drill into the oxygen cylinder. The cylinder had two diamond-shaped labels, one of which was above

the other and clearly marked with the word "OXIDIZER" **(Exhibit 3).** The other label may have read the same, but was unreadable after the incident since the decedent drilled through the middle of it.

While drilling through the cylinder, it suddenly exploded. The decedent was thrown about 15 feet where he struck his head on a stationary band saw. There were three employees who were in the area of the explosion--a shipfitter journeyman, a sheetmetal worker and a sheetmetal mechanic journeyman. They all stated that they heard a loud noise and saw something fly through the air and land near the band saw. The sheetmetal mechanic journeyman ran to the decedent's aid, placed his hand on him and asked if he was okay. He received no response. He then ran to call security and advised them of the incident. He ran back to the decedent and applied pressure to his bleeding temple. No CPR was attempted prior to the arrival of medical assistance.

The paramedics were dispatched at 7:12 a.m. and arrived at 7:20 a.m. The found the patient to have an open skull fracture, fractured ribs, no pulse and no spontaneous respiration. He was transported by the paramedic ambulance with CPR in process to a local hospital where he was pronounced dead at 7:50 a.m. The oxygen cylinder on which the decedent was working had a valve cap which was rusted in place. It is unknown how much pressure the cylinder had in it at the time of the incident, but such cylinders are filled at 2200 to 2600 pounds per square inch. Since the cylinder was not leaking, it is possible that it was fully pressurized.

When the decedent drilled into the cylinder, several circumstances existed which may have caused or contributed to the incident. Primarily, oxygen is a rapid oxidizer and can cause materials which will not burn in air to burn rapidly or explosively. The metal from which the oxygen cylinder was made is carbon steel. Carbon steel burns at very low pressures in oxygen-enriched atmospheres. Ignition may have been caused by the friction, and resulting heat build up of the drill bit cutting into the metal. Ignition may have also been caused by the sparking of the drill's motor. One additional factor is the kindling effect of the metal particles caused by the drilling and/or of the rust particles on the inside of the cylinder.

Although oxygen is not flammable by itself it supports combustion. Ignition usually begins as a small event and grows into a fire through the kindling chain sequence. The drilling and/or rust particles, once ignited, gave off enough heat to ignite the cylinder's shell. The hole in the cylinder which resulted was not jagged, but smooth and melted in nature as if flame cut (refer to exhibit 4). It burned from the original, small hole, outward until the fire was quenched. The resulting hole in the cylinder shell was 2 5/8 inches in diameter. No metal pieces were found in the area or in the victim. The metal, which burns as a liquid, was vaporized. The slag formed was thrown out as small pieces and explains the small abrasions on the victims chin and chest. The victim, although not burned, had what was described as sooty material over most of his body. This would be the iron oxide formed when the metal burned.

The fire was of very short duration. Research indicates that the flame lasted from 1/2 to a maximum of 2 seconds. This partially explains why the victim was not burned. The other explanation is that the extreme pressure of the gas coming through the small hole in the side of the cylinder blew the victim quickly away from the cylinder and into the band saw. One cannot be certain, but the oxygen gas escaping may have reached sonic velocity and caused a pressure shock. This may also have been responsible for the decedent being propelled through the air.

CAUSE OF DEATH

The coroner's report stated the cause of death to be head trauma with skull fracture and temporal lobe laceration.

RECOMMENDATIONS/DISCUSSION

Recommendation #1: Employers should assure each gas cylinder marked for destruction is labeled or marked to differentiate them from those not ready for destruction.

Discussion: In this incident the acetylene cylinders slated for destruction were marked with the same designation as was the oxygen cylinder involved in the explosion, an "X" surrounded by a circle. If employees were focused on that marking, they could mistakenly assume that all compressed gas cylinders having such a mark would be ready for destruction and salvage. Since it was not necessary to drill into an oxygen cylinder, the decedent must have assumed that it was one of the acetylene cylinders. Had the oxygen cylinder not been marked with an "X" surrounded by a circle, the decedent most likely would not have began the destruction process and this incident may not have happened.

Recommendation #2: Employers should use an unmistakable marking on cylinders that have been prepared for salvage or destruction.

Discussion: Although the employer used a mark to indicate that the cylinder was prepared for salvage, this mark was used on cylinders which were not ready. It is industry standard to use the marking "MT" on cylinders which have been depressurized by bleeding off the compressed gas contents. "MT" is the marking which indicates the cylinder is empty. When cylinders were depressurized, they should have been marked with standard "MT" designation to indicate that they were depressurized. Other markings could be used, including an "X" surrounded by a circle to indicate that a particular cylinder should be destroyed. If employees understood that cylinders that are not marked with the "MT" designation are not depressurized, then the subject oxygen cylinder may not have been loaded onto the trolley and been subjected to the destruction process.

Recommendation #3: Employers should prepare an appropriate written program describing the procedures for the destruction and salvaging of compressed gas cylinders.

Discussion: In this incident there was no written program to describe how the destruction of compressed gas cylinders should be done. There were at least five different types of compressed gases in cylinders at the location of the incident. Each gas should have its own particular destruction process detailed in writing. Cylinder destruction at this company was verbally handed down through three levels of company hierarchy. The danger is that all of the information necessary may not have been communicated to the level of employee who must perform the job. Obviously, a mistake was made in the marking of the cylinders slated for destruction. Moreover, the decedent either ignored or did not understand the "OXIDIZER" label on the oxygen cylinder. Since acetylene cylinders are not so marked, a formal, written program, and subsequent training, would have revealed that something was wrong in the process. Such a revelation most likely would have prevented the decedent from proceeding and the explosion most likely would have

been avoided.

Recommendation #4: Employers should use an appropriate method for the destruction of pressurized compressed gas cylinders.
Discussion: In this incident the oxygen cylinder could not be relieved of pressure because the valve cap was frozen by rust. It was, therefore, impossible to access the valve so pressure could be bled off. In such cases, compressed gas cylinders should be placed and secured in a sand bag bunker. They should be shot with a bullet with enough power to penetrate the cylinder wall. Another method which could be used, is to set up a remote drilling operation. However, because a fire and explosive force will result with some gases, the drill may be destroyed. Had the oxygen cylinder been secured in a sand bagged bunker and relieved of pressure remotely, this fatality would not have happened.

References:

Accident Prevention in Oxygen-Rich and Oxygen-Deficient Atmospheres, (P-14), Compressed Gas Association, Inc., Arlington, VA

Barclays Official Code of Regulations, Vol. 9., Title 8, Industrial Relations. South San Francisco, CA, 1990

Material Safety Data Sheet: No. 205, Oxygen; Liquid Carbonic, Chicago, IL, October 1991

National Fire Protection Association, Guide on Fire Hazards in Oxygen-Enriched Atmospheres, NFPA 53, Quincy, MA, 1996
Oxygen, (G-4), Compressed Gas Association, Inc., Arlington VA

Recommendations for the Disposition of Unserviceable Compressed Gas Cylinders with Known Contents, (C-2), Compressed Gas Association, Inc., Arlington, VA

Sircar, S., Stoltzfus, J., Bryan, C., and Kazaroff, J., "Promoted Combustion of Pure Metals in Oxygen-Enriched Atmospheres'" Flammablity and Sensitivity of Materials in Oxygen-Enriched Atmospheres: 7th Volume, ASTM STP 1267, Dwight D. Janoff, William T. Royals, and Mohan V. Gunaji, Eds. American Society for Testing and Materials, Philadelphia, PA, 1995

Standard Guide for Control of Hazards and Risks in Oxygen Enriched Systems, (G 128-95), American Society for Testing and Materials, Philadelphia, PA, March 1995

Stoltzfus, Joel, National Aeronautics and Space Administration, White Sands Test Facility, Las Cruces, NM, personal telephone interview, September 12, 1997

Richard W. Tibben, CSP
FACE Investigator

Robert Harrison, MD, MPH
FACE Project Officer

Judie Guerriero, RN, MPH
Research Scientist

****

FATALITY ASSESSMENT AND CONTROL EVALUATION PROGRAM

The California Department of Health Services, in cooperation with the Public Health Institute and the National Institute for Occupational Safety and Health (NIOSH), conducts investigations of work-related fatalities. The goal of this program, known as the California Fatality Assessment and Control Evaluation (CA/FACE), is to prevent fatal work injuries in the future. CA/FACE aims to achieve this goal by studying the work environment, the worker, the task the worker was performing, the tools the worker was using, the energy exchange resulting in fatal injury, and the role of management in controlling how these factors interact. NIOSH-funded, state-based FACE programs include: Alaska, California, Iowa, Kentucky, Massachusetts, Michigan, Minnesota, Nebraska, New Jersey, New York, Oklahoma, Oregon, Washington, West Virginia, and Wisconsin.

****

Additional information regarding the CA/FACE program is available from:

California FACE Program
California Department of Health Services
Occupational Health Branch
850 Marina Bay Parkway, Building P, 3rd Floor
Richmond, CA 94804